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A UNICONTROL HIGH-FREQUENCY RADIO DIRECTION FINDER

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ABSTRACT

The Bureau of Standards was asked to develop for the United States Coast Guard a simple type of radio direction finder which should function on 2,100 kc (143 m). Such a device enables a ship equipped with it to locate another ship readily. This paper describes the development of such a direction finder and its installation on a Coast Guard patrol boat. The direction-finder coil consists of four turns of ignition cable wound on a 20-inch frame. It is installed over the pilot house and rotated from below. A tuning unit and coupling transformer have been designed so that the direction-finder coil may be used on the ship's receiving set without changing its tuning adjustments, which are locked in the 2,100-kc position. A special form of automatic balancing condenser operated by a special cam rotating with the direction-finder shaft is incorporated in this instrument whereby a clear minimum may be obtained at all angular positions of the coil without manual operation of the balancing condenser. The controls necessary when taking a bearing are thus reduced to one—that of rotating the direction-finder coil to obtain the minimum signal.

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I. INTRODUCTION

In 1922 the Bureau of Standards [1] published a technical paper on the radio direction finder as an aid to navigation. Since that time the use of the radio direction finder on shipboard has become common and has proven one of the greatest aids to navigation [2] in fog. The United States Coast Guard has recently found that the radio direction finder is useful in its service for enabling one ship to locate another

[1] F. A. Kolster and F. W. Dunmore, The Radio Direction Finder and Its Application to Navigation, B. S. Sci. Paper No. 428.

[2] George R. Putnam, Radio Fog Signals and Their Use in Navigation in Connection with the Radiocompass, 2d ed.; 1924.

in order to relieve it from patrol duty or for locating ships in need of assistance. Recently a fleet of small coast patrol boats have been added to the Coast Guard Service. These boats are equipped with radio telephone and telegraph transmitting and receiving apparatus which operates at a frequency of 2,100 kc per second (143 m). At the request of the Coast Guard the Bureau of Standards developed a special type of radio direction finder for these boats that would give satisfactory service at this frequency. It is described in this paper.

II. GENERAL REQUIREMENTS AND DESCRIPTION

FIG. 1.—*Experimental model of high-frequency radio direction finder on Coast Guard patrol boat*

The conditions of use of a direction finder on these boats made necessary the following features. First, since personnel unskilled in radio were to be the operators of the direction finder, the number of controls had to be the fewest possible. Second, the direction finder had to operate without alteration of the receiving equipment installed on the patrol boats. The tuning adjustments of this set are locked at 2,100 kc. It was therefore necessary to design the direction finder to operate at this frequency without unlocking the adjustments. The A batteries and receiving set shield were grounded, which added considerably to the problem.

Preliminary work was done with an experimental model shown in Figure 1. The direction finder as finally developed consists of a four-turn, 20-inch square coil located over the pilot house and rotatable from within the pilot house. This coil is connected to a special coupling transformer, the primary of which is part of the coil circuit and the secondary of which is connected to the receiving set by including the antenna coupling coil already in the receiving set as part of the tuned secondary circuit. Both primary and secondary circuits are tuned to 2,100 kc. This type of connection makes possible the use of the receiving set on the direction-finder coil without change in connection, since the received power is transferred to the receiving set through the antenna coupling coil in the receiving set in the normal way. A balancing condenser with

movable plates grounded is connected in parallel with the direction-finder coil tuning condenser. This balancing condenser is automatic in operation, being operated as the direction-finder coil is rotated by a cam on the direction-finder shaft. A single-pole double-throw switch is provided for connecting the receiving set either to the ship's antenna or to the direction-finder circuit. The ship's antenna switch is opened when taking bearings.

The Coast Guard patrol boat, for which this direction finder was primarily developed, has recently been put into use to render more effective the Coast Guard patrol service. A photograph of one of these boats is shown in Figure 2. Figure 3 shows the location of the direction-finder coil over the pilot house.

FIG. 2.—*Coast Guard patrol boat with high-frequency radio direction finder installed*

III. DESCRIPTION OF INSTALLATION ON COAST GUARD PATROL BOAT "No. 198"

The installation on Coast Guard patrol boat *No. 198*, a typical one, consists of the following apparatus: (*a*) Direction-finder coil; (*b*) shaft, brushes, scale, cam, and hand wheel; (*c*) tuning condensers and balancing transformers; (*d*) automatic balancing condenser; and (*e*) receiving set.

The general arrangement of apparatus is shown in Figures 4 and 5.

1. DIRECTION-FINDER COIL

This coil, which is 20 inches square, consists of four turns of rubber-covered ignition cable 7 mm in diameter. The winding is in two sections, the sections being 2 inches apart and the wires in the sections five-eighths inch apart.

2. SHAFT, BRUSHES, SCALE, CAM, AND HAND WHEEL

The shaft consists of a 1½-inch brass pipe mounted on ball bearings. Two leads from the terminals of the direction-finder coil extend through the shaft from the coil to the slip rings at the lower end of the shaft.

The shaft also carries a special scale engraved in green from 0 to 180° counterclockwise and in red from 0 to 180° clockwise. The color is to facilitate the reading of bearings in the proper relation with respect to the ship's head.

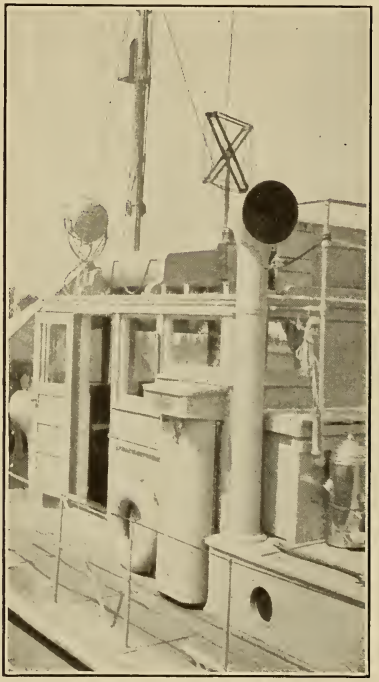

FIG. 3.—*Pilot house of Coast Guard patrol boat showing location of radio direction finder*

The cam shown under the scale (fig. 4) is for the purpose of operating the automatic balancing condenser. This cam, which is of the adjustable type, is shown in detail in Figure 6. It is made of 24 adjustable sections, which when adjusted separately may be made to give any desired cam shape. The method of determining the shape of this cam will be discussed later. A hand wheel is attached to the shaft for rotating the direction-finder coil.

3. TUNING CONDENSERS AND COUPLING TRANSFORMER

The tuning condenser and coupling transformer make possible the operation of direction finder on the 2,100 kc (143 m) receiving sets already installed on the patrol boats without changing the dial settings of this set, which have been locked in position for reception on the boat's antenna on 2,100 kc. A further object, and one for which the coupling transformer was designed, is to make possible reception with the batteries and shields grounded, as this connection can not be altered. The shielded box containing the locked tuning condensers, coupling transformer, and automatic balancing condenser is shown in Figure 7. Figure 8 is an inside view. The circuit diagram is shown in Figure 9. The condenser for tuning the direction-finder coil circuit to a frequency of 2,100 kc is shown at *M*, Figure 9. It is adjusted after installation by placing a special

screw driver made of insulating material in the slotted end of the condenser shaft (see fig. 7). This adjustment is made through a hole in the cover. The condenser is then locked in position by means of a clamping device.

A similar condenser, *N*, is included in the secondary circuit, by means of which this circuit is likewise tuned permanently to 2,100 kc. This circuit includes the antenna-coupling coil unit, *P*, in the receiving set. The power received in the direction-finder coil circuit is thus transferred to the tuned secondary circuit of the receiving set in the normal way. The secondary circuit is kept locked at the 2,100 kc position for reception on the ship's antenna. The receiving set is thus used under practically the same conditions on both antenna and direction-finder circuit, the only difference being that the input coupling coil circuit is untuned when used in the antenna circuit and tuned when used in the direction-finder circuit. The direction finder may thus be operated on the receiving set without altering its tuning adjustments by merely throwing switch *S*. The primary of the coupling transformer, *R*, consists of six turns of No. 24 AWG d. c. c. wire spaced three thirty-seconds inch apart and wound on a piece of insulating tubing 1 inch in diameter. The secondary coil, *D*, consists of 47 turns of No. 30 AWG wire single silk enamel close wound with a space of three-fourths inch between the two coils *R* and *D*. These coils are shown in Figure 8.

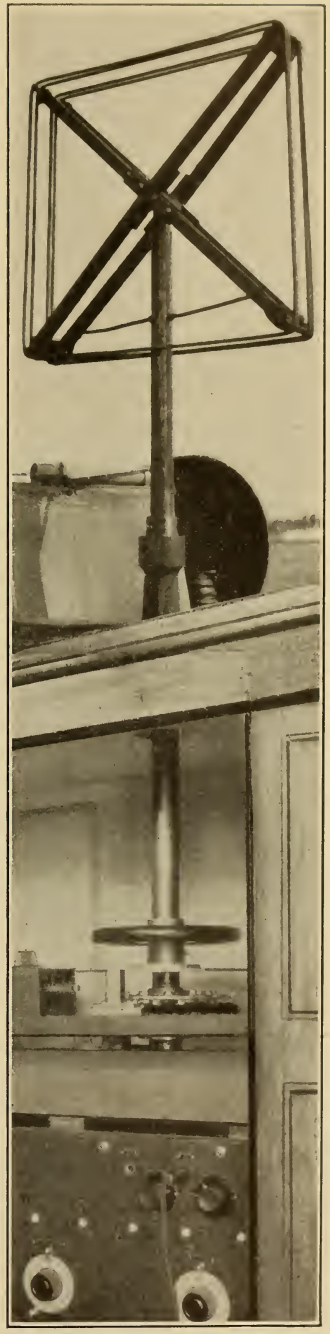

FIG. 4.—*High-frequency radio direction finder with cam-operated balancing condenser*

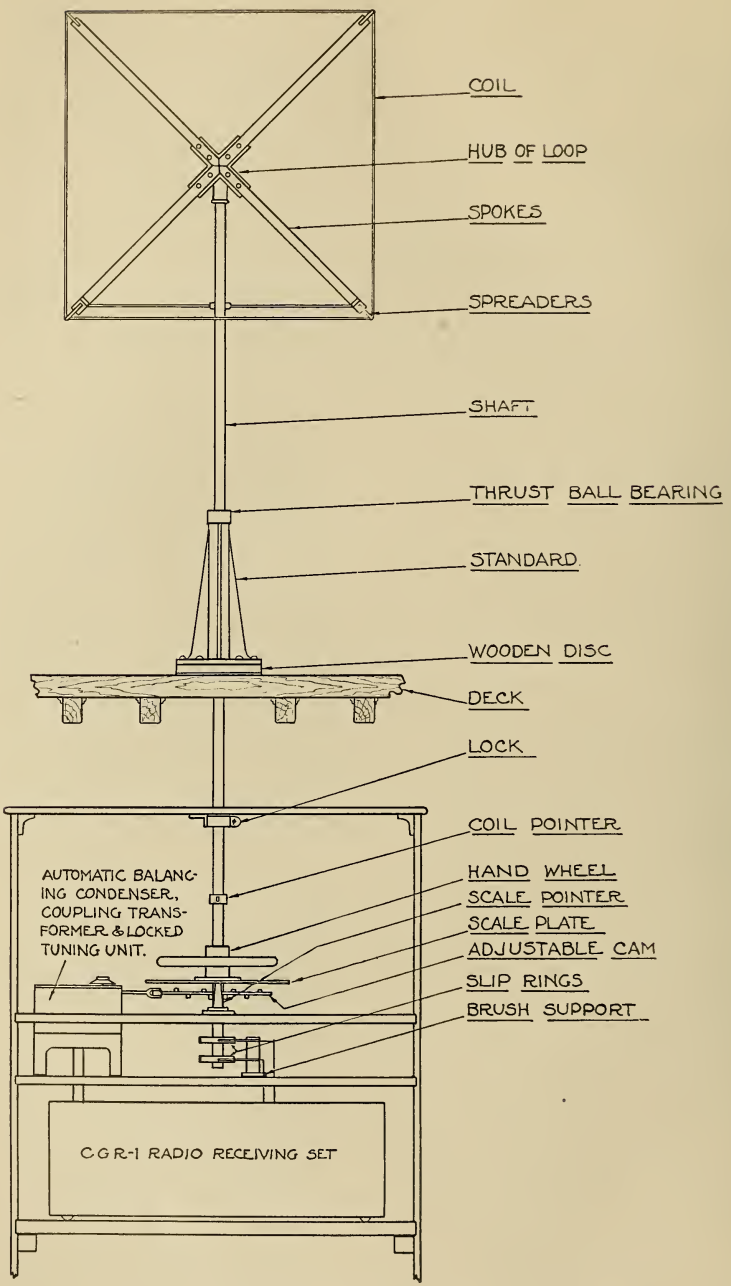

FIG. 5.—*Installation of high-frequency direction finder*

4. AUTOMATIC BALANCING CONDENSER

In order to make the operation of this direction finder the simplest possible, the manual adjustment of the balancing condenser for sharpening the minimum when taking bearings was eliminated and a cam-operated balancing condenser devised. This device is shown in Figures 7 and 8. The position of the balancing condenser relative to the cam is shown in Figure 5. The setting of the balancing condenser is determined by the shape of the cam. The rack engages a gear made of insulating material attached to the shaft of the balancing condenser, and the roller is held against the cam by means of a spring.

It has been found that the setting of a balancing condenser is dependent on the angular position of the direction-finder coil with

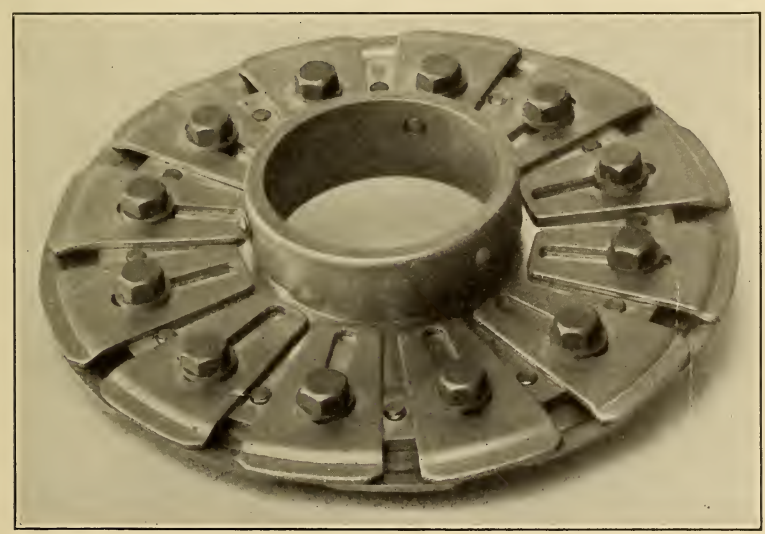

FIG. 6.—*Adjustable cam used on shaft of high-frequency direction finder for automatically operating the balancing condenser*

respect to the ship's center line and neighboring guys, antennas, etc. These fixtures remaining permanent, the settings of the balancing condenser are dependent on each angular position of the direction-finder coil through the 360° of rotation. The adjustable cam rotating with the direction-finder coil shaft may be shaped to set the balancing condenser at its proper value for each angular position of the direction-finder coil, so that a sharp minimum may be obtained throughout the full 360° without complicating the operation of the direction finder.

5. RECEIVING SET

The receiving set used with this direction finder is the one installed as part of the ship's equipment. It is a Coast Guard Type

CGR–1 receiving set.[3] This receiving set is of the superheterodyne type, consisting of a high-frequency oscillator, first detector, three stages of intermediate frequency (50 kc) amplification, second detector, one stage of audio-frequency amplification, and a low-frequency oscillator for CW reception. A s. p. d. t. switch is placed near the receiver for the purpose of changing the receiving set from direction-finder coil to ship's antenna.

IV. CAM ADJUSTMENT AND CALIBRATION

The proper cam shape is determined experimentally after the direction finder has been installed. The process is as follows: After

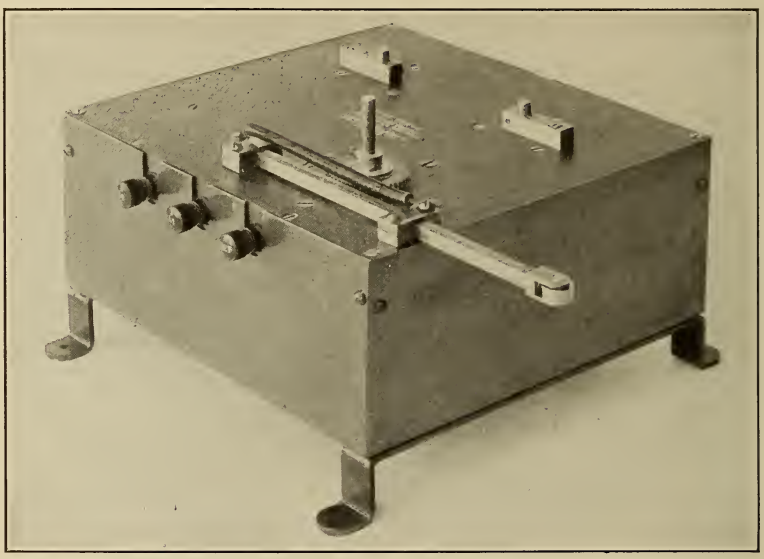

FIG. 7.—*Copper box containing the cam-operated balancing condenser, tuning condensers, and coupling transformer*

the apparatus has been tuned to 2,100 kc and all adjustments locked the cam is slipped up or down on the shaft, so that the balancing condenser may be operated by hand without the roller engaging the cam. The spring is removed from the rack arm and the cover and dial replaced. A boat carrying a low-powered transmitting set operating at 2,100 kc is then cruised around the direction finder at a distance of one-quarter mile or more. A small boat was used for calibrating the direction finder on the Coast Guard patrol boat *No. 198*. A sight bearing on the boat carrying the transmitting set is maintained as well as the radio bearing, care being taken to keep the coil pointer on the shaft toward the calibrating boat. A sharp

[3] Anderson, S. E.; Clement, L. M.; DeCoutouly, G. C., "Recent commercial development in short-wave transmitters and receivers," Proc. I. R. E., **13**, pp. 413–436; August, 1925.

minimum is maintained by adjusting the balancing condenser. At the instant the calibrating boat is sighted dead ahead the direction finder is locked at the position, giving the minimum signal at that instant. The scale is then loosened on the shaft and revolved until it reads zero. It is then clamped firmly in position. As the boat moves around the direction finder, radio bearings are taken every 5 or 10° as well as the corresponding readings of the dial on the balancing condenser which are found to give the sharpest minimum. It is important to keep the pointer on the direction-finder shaft toward the calibrating boat at all times. After the 360° have been covered the cam is slipped and locked in position to engage the roller and the angular position of the direction-finder coil, and the

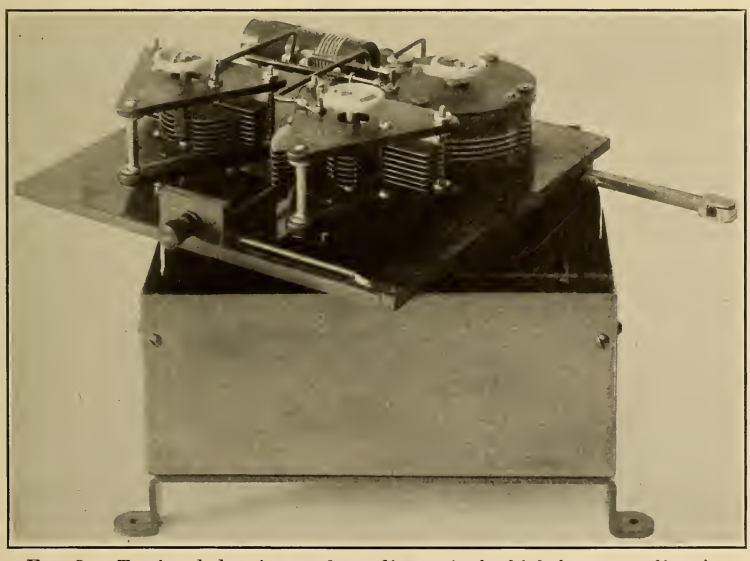

FIG. 8.—*Tuning, balancing, and coupling units for high-frequency direction finder*

corresponding balancing condenser settings are duplicated and the cam adjusted to just touch the roller at each duplicated setting. The spring is then replaced on the rack arm, and the roller is thus made to run on the periphery of the cam, whose shape is such that each angular position of the direction-finder coil maintains the proper setting of the balancing condenser to give the best minimum, as found by experiment.

This adjustment having been made, the direction finder may be calibrated without thought of the balancing condenser, as its operation has become automatic. A direction-finder calibration is the determination of the difference between the sighted and radio bearing on the calibrating boat through the 360° of rotation of the direction-

finder coil. The differences thus obtained are thereafter added to or subtracted from a radio bearing, thus giving the true bearing. The maximum difference in the case of the calibration for the direction finder on the Coast Guard patrol boat *No. 198* was about 5°.

As the major use of this direction finder is for taking bearings to proceed to another ship which is transmitting for the purpose of being located, most bearings will be taken dead ahead, thus eliminating the necessity of making a calibration correction.

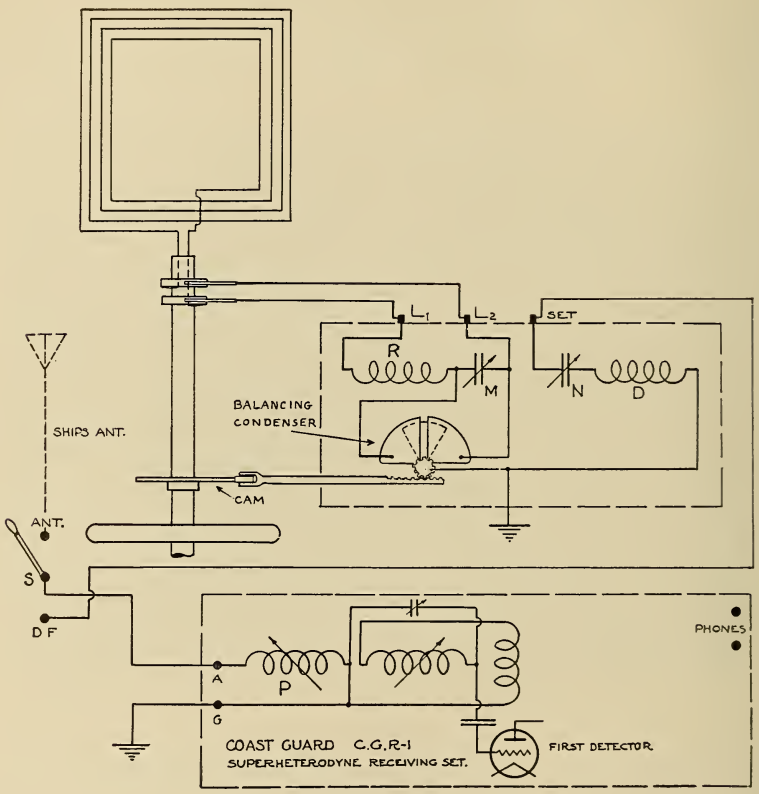

FIG. 9.—*Direction-finder circuit*

V. CONCLUSION

The type of direction finder as described, while operating at a radio-frequency higher than has been customary for direction-finding purposes, has proven to be a satisfactory device on a small type of boat, such as the Coast Guard patrol boat. While tests have not been made to determine its efficacy on a larger ship, it is thought that such use may be possible if care is taken to prevent the natural frequencies of stays, guys, antennas, etc., from approaching that of the radio-frequency used for direction finding.

It is expected that errors due to radio wave transmission phenomena will be more pronounced when working over long distances on high frequencies than with the lower frequencies commonly used. The errors due to transmission phenomena are not great over short distances, therefore do not seriously affect the accuracy of the direction finder, which will generally be used in this service to take the bearing of a near-by vessel in order to proceed to it.

The author wishes to acknowledge the splendid cooperation and assistance rendered by Lieut. Commander E. M. Webster and W. W. Reynolds, of the United States Coast Guard.

WASHINGTON, January 25, 1926.